TRAINING and QUALIFICATIONS OFFICE

BROOKHAVEN
NATIONAL LABORATORY

GENERAL EMPLOYEE RADIOLOGICAL TRAINING (RWT001)

STUDY GUIDE

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LEARNING OBJECTIVES

To receive credit for completion of this training course, each participant will be required to attain a grade of 80% or greater on a 20 question multiple-choice examination covering the following objectives.

- Differentiate between radioactivity, radioactive material and radiation generating device.
- Identify the unit used to measure radioactivity.
- Differentiate between non-ionizing and ionizing radiation.
- Identify the four types of ionizing radiation
- State the meaning of the radiation unit rem.
- Differentiate between occupational and non-occupational radiation dose
- Identify the average annual radiation dose from non-occupational sources
- Differentiate between acute and chronic radiation effects
- Identify the annual radiation dose that a GERT qualified worker is expected not to exceed.
- State the potential effects associated with prenatal radiation dose
- State the BNL policy concerning a declared pregnant worker.
- Identify the primary risk associated with occupational radiation dose
- Compare occupational risk from radiation to health risks in industry and daily life.
- State the purpose and identify proper use of personal dosimetry
- Apply the concepts of using Time, Distance and Shielding to reduce radiation dose.
- Identify the authorities granted to GERT trained individuals concerning access to radiological areas and control of radioactive materials
- State the BNL management policy for the ALARA program.
- Identify the purpose and scope of the Price Anderson Amendment Act (PAAA) and 10CFR835 regarding matters involving radiological protection at BNL.
- Identify the purpose and scope of the BNL policy regarding your responsibility and authority for stopping non-compliant radiological work.
- State the purpose of the BNL Radiological Awareness Report (RAR) Program.

Introduction

The Department of Energy, in conjunction with Brookhaven National Laboratory, is firmly committed to having a radiological control program of the highest quality. This program as outlined in the BNL Radiological Control Manual, requires all individuals including their supervisors and managers to be involved in the planning, scheduling and conduct of radiological work. This directive also requires that adequate radiological safety shall not be compromised to achieve production or research objectives.

To accomplish this goal, all personnel who may encounter radiation or radioactive materials while performing their job must be informed of the potential effects and the policies and procedures in place to minimize their risk.

General Employee Radiological Safety Training (GERT) provides the core level knowledge needed to safely enter and work within Controlled Areas at Brookhaven National Laboratory. While attending this course, participants are introduced to fundamental radiation protection concepts, types and sources of radiation and risks associated with receiving low level occupational exposure. In addition, the course applies the fundamental radiation protection knowledge to DOE / BNL radiation protection policies, procedures and the philosophy of maintaining radiation dose As Low As Reasonable Achievable (ALARA).

Overview

Within the context of this course, the term "employee" is used to include BNL/BSA employees, contractors, guests, and visitors. General Employee Radiological Training (GERT) is provided to all employees who enter Controlled Areas and encounter radiological barriers, postings or radioactive materials. Although the GERT trained employee may enter Controlled Areas without an escort, they may not enter any areas of greater control (such as a Radiation Area, Radiological Buffer Area, Contamination Area, etc.) without an escort. While under escort, the GERT trained worker can do no work unless having received pre-authorization by the Radiological Controls Division as prescribed by the BNL Radiological Control Manual. Employee responsibilities for observing and obeying radiological postings and procedures are emphasized throughout this training.

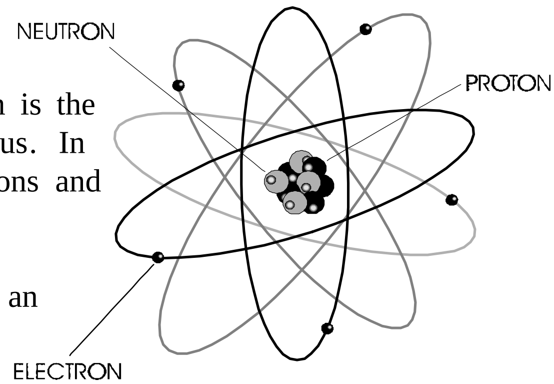
Every employee, both radiological worker and non-radiological worker, must play an active part in maintaining exposures to radiation and radioactive materials to As Low As Reasonably Achievable (ALARA). In order to do this, we need to develop a sense of pride and ownership toward our daily activities and have a healthy respect, rather than a fear for the type of work performed at BNL.

In other words, we should be able to place the risks associated with working at a research facility (that uses radiation and radioactive materials) in perspective with other risks that we take in our everyday life.

Differentiate between radioactivity, radioactive material and radiation generating device

Atomic Structure

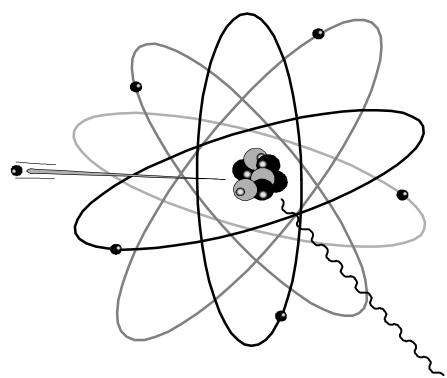
All of the materials we work with, whether they are gas, liquid, solid, plant, animal or mineral, are composed of atoms. Atoms are the smallest unit of matter that retain the properties of an element (such as carbon, lead, and helium). The atom can be described as having three basic particles.



The central core of the atom, called the nucleus, is made up of protons (positively charged) and neutrons (no charge). The third part of the atom is the electron (negatively charged) which orbits the nucleus. In general, each atom has an equal number of protons and electrons so the atom is an electrically neutral unit.

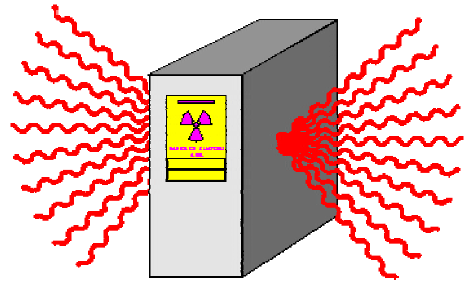
An element is a substance made up of atoms bearing an identical number of protons in each nucleus. Most of the atoms of an element also have the same number of neutrons in each nucleus, but not always. If atoms have the same number of protons, but a different number of neutrons, they are called isotopes of the element. They retain the same chemical properties of the element, but may exhibit different nuclear properties, such as radioactivity.

Radioactivity



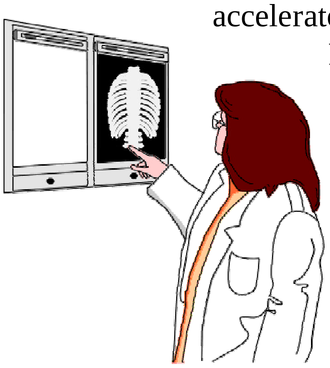
Radioactivity is the property of certain atoms to spontaneously emit particle or electromagnetic wave energy. The nuclei of some atoms are unstable, and eventually adjust to a more stable form by the emission of radiation. These unstable atoms are called radioactive atoms or radioactive isotopes. Radiation is the energy emitted from the radioactive atoms, either as electromagnetic waves or as particles. When radioactive (or unstable) atoms adjust, it is called radioactive decay or disintegration.

Radioactive Material



Any material containing radioactive atoms is called either radioactive material or a radioactive source. These sources can be readily identified because of the characteristic radiation energy being emitted. Sources of radioactive materials are not confined to nuclear power plants and research facilities such as BNL. As we will find out later in the training course, you routinely encounter radioactive materials in everyday life.

Radiation Generating Devices



Radiation Generating devices are machines that typically do not contain radioactive materials or sources but create radiation fields when operated. Except in the case of BNL's high-energy accelerators such as the Alternating Gradient Synchrotron (AGS), the Relativistic Heavy Ion Collider (RHIC), or the Radiation Treatment Facility (RTF) when radiation generating devices are not operating, external radiation hazards do not exist. In addition, radiation exposure can readily be controlled as part of the devices operating procedure. This is accomplished by ensuring all personnel are removed from the vicinity of the machine before it is operated and by using locked doors and warning lights, commonly referred to as interlocks, to restrict access to the hazard during operation.

Types of radiation generating devices at BNL include:

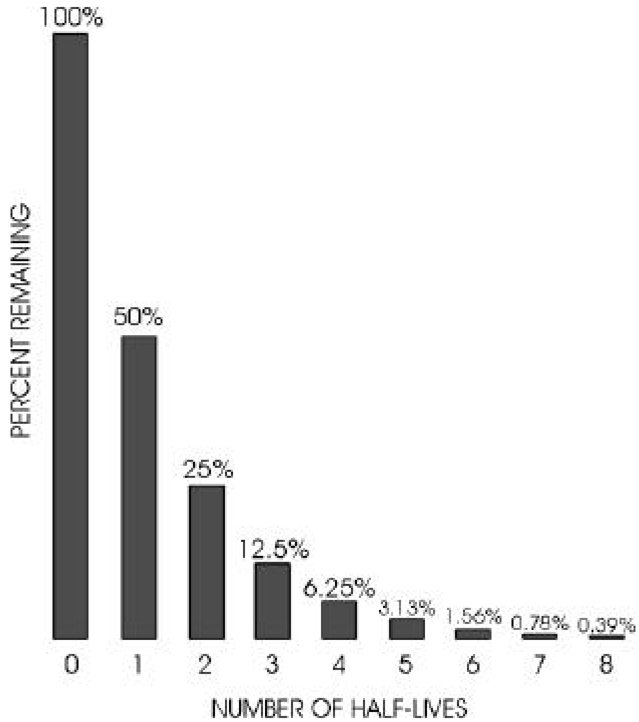
- Diagnostic X-ray machines used at the Occupational Medicine Clinic
- Therapeutic X-ray machines used at the Radiation Therapy Facility
- Analytic X-ray machine machines used for research of atomic structure
- DT Generator (deuterium to tritium) used to produce high-energy neutrons for research.

Personnel assigned to operate these devices must be trained in their safe use before allowing them to utilize the machine as part of their job.

Identify the unit used to measure radioactivity

Measuring Radioactivity

The process of radioactivity is a natural phenomenon. All radioactive materials undergo this process in an attempt to become non-radioactive. Radioactive half-life is a measurement used to express the amount of time it takes for a particular radioactive material to decay to one half of its original value. Thus, after one half-life only 50% of the original radioactivity remains, after two half-lives 25%, after three, 12.5% and so on until eventually none of the original radioactive material remains.



Radioactivity is measured in units that are equivalent to the number of radioactive decays occurring each second, commonly referred to as disintegrations per second (dps). The unit of measure is the Curie (Ci) where one curie equals thirty seven billion disintegrations per second.

1 Ci = 37,000,000,000 dps or 3.7×10^{10} dps.
1 Ci = 2,200,000,000,000 dpm or 2.2×10^{12} dpm.

A measurement program called System International (SI) uses the unit Becquerel (Bq) to measure radioactivity. A Becquerel is equal to a single disintegration per second.

1 Bq = 1 dps

This system is not widely used for routine operations at BNL, but will often be encountered in scientific journals, research papers or reference documents.

Differentiate between non-ionizing and ionizing radiation.

Radiation

Radiation is merely energy in the form of electromagnetic waves or sub atomic particles. Radiation is emitted from radioactive atoms and is generated during the interaction of radiation with matter or from a radiation-generating device such as microwave generators, radio-frequency generators such as television and radio transmitters, X-ray machines and lasers.

Radiation that has insufficient energy to remove electrons from atoms within material is classified as **non-ionizing radiation.** Examples of non-ionizing radiation include most visible light, infrared light, microwaves and radio waves.

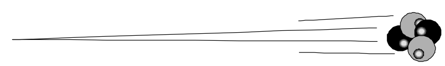
When radiation has sufficient energy to remove electrons from atoms, a process known as ionization, the radiation is classified as **ionizing radiation**. For the purposes of training course, examples of ionizing radiation include alpha, beta, gamma or x-ray and neutron.

There should be no misunderstanding, ALL TYPES OF RADIATION either non-ionizing or ionizing may pose health risks. You may be aware of recent discussions regarding risks associated with exposure to microwave radiation or cellular phone transmission which are both non-ionizing radiation sources. For the purposes of this training we will focus our attention to the hazards and risks of exposure to ionizing radiation only. Thus for the remainder of this course, the term "radiation" refers only to ionizing radiation.

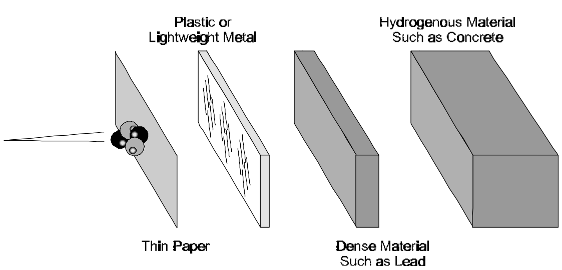
Identify the four types of ionizing radiation

Alpha particles

Alpha particles are charged particles containing two protons and two neutrons that are emitted from the nuclei of certain heavy atoms, such as uranium when they decay. Because of its size and charge, an alpha particle only travels a few centimeters in air. It can also be stopped or shielded using a sheet of paper.



ALPHA Radiation
A Particle Containing 2 Protons and 2 Neutrons
Moving at High Speed

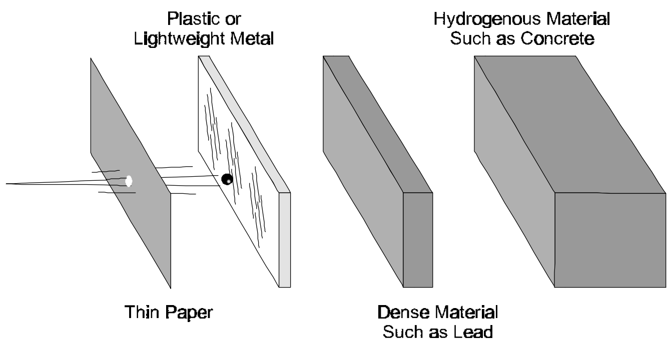


The alpha particle cannot penetrate the dead layer of human skin, but may be very damaging if the source of alpha radiation is inside the body. There are only a few sources of alpha radiation at BNL. These are primarily in laboratories in the form of uranium and thorium salts.

Beta particles

Beta radiation is a particle with the mass of an electron emitted, with energy, from many different radioactive atoms. Betas with a positive charge are called positrons.

BETA Radiation
A Particle having the Mass of an Electron
Moving at High Speed



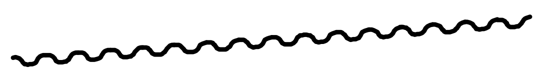
Both are likely to interact and deposit their energy as they pass through surrounding matter. Their range in air can be as far as 10 feet.

Beta particles can typically be shielded by using 3/8" of plastic or thin lightweight metals such as 1/8" of aluminum. Because beta particles can penetrate the dead layer of skin and affect the live skin tissue, they can cause serious injury to the skin and also to the eyes. Some sources of beta radiation at BNL include tritium (^{3}H), phosphorous (^{32}P), carbon (^{14}C), sulfur (^{35}S) , and strontium (^{90}Sr).

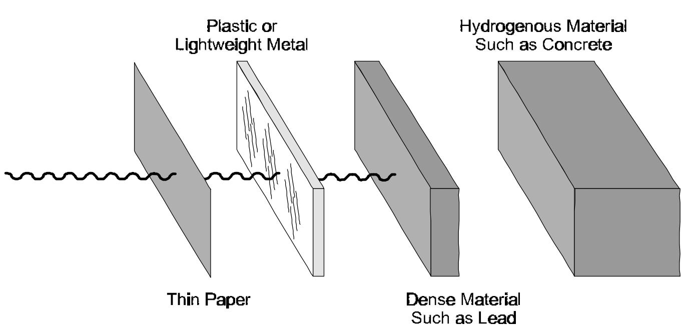
Beams of high energy electrons are also generated in our accelerators, but these are not usually termed beta particles. These electrons can penetrate deep into the body and as a result, require much heavier shielding. Personnel are protected from the accelerator beams by the use of appropriate shielding and interlocks to prevent access.

Gamma and X-rays

Gamma and x-rays are electromagnetic radiation with no mass or charge. Gamma rays are generally emitted from the nucleus during radioactive decay, while x-rays are emitted from orbital electrons. Electromagnetic radiation may also be given off by a charged particle accelerating or decelerating in an electric field. This is the major source of radiation at facilities such as the National Synchrotron Light Source (NSLS).



GAMMA / X-RAY Radiation
Electromagnetic Wave

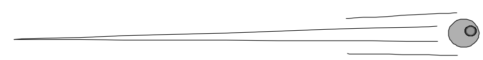


Because they have no mass and no charge, gamma and x-rays are very penetrating forms of radiation. In air, high energy gamma or x-rays may travel several hundred feet. Dense materials such as lead are used for shielding. From a biological perspective, x-rays and gammas are considered external hazards, meaning that even with the source of radiation outside your body, the radiation can penetrate and affect internal organs.

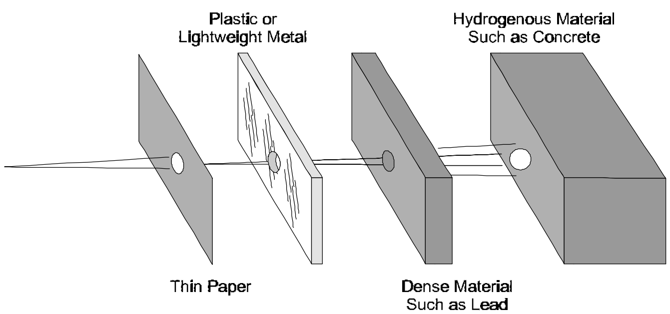
Gamma radiation is the major contributor to the total dose at the Brookhaven National Laboratory. Some of the major sources of gamma radiation at BNL include the particle accelerators, reactors, and some of the radionuclides used in the various labs.

Neutrons

Neutrons are neutral particles emitted from the nucleus during fission (splitting of an atom), emitted as part of the radioactive decay of californium, and are given off as secondary radiation from interaction of other high energy radiations with matter.



NEUTRON Radiation
Neutron Moving at a High Speed



Because they have no charge, neutrons can be a very penetrating form of radiation and can travel several hundred feet in air. At high energies, they transfer energy by collision with light atoms, especially hydrogen. At lower energies, neutrons can be absorbed and the absorbing material can become radioactive. Neutrons, like the x-rays and gammas, are considered an external hazard. Shielding that is most effective for neutrons includes water, paraffin, boron, cadmium and concrete.

Sources of neutrons at Brookhaven Lab include the Brookhaven Medical Research Reactor (BMRR), accelerators such as the Alternating Gradient Synchrotron (AGS) or relativistic Heavy Ion Collider (RHIC), and isotopic neutron sources maintained on site.

Sources of Radiation from Accelerators

Beams of protons, electrons, or heavy ions are accelerated and aimed at targets for various experiments. Workers are protected from the beam lines by specially designed shielding and interlock systems. Radiation doses to personnel during operations are primarily the result of secondary radiation caused by the beam striking a target, hardware, or shielding that surrounds the beam line. This radiation dose to personnel is mostly from gamma rays and neutrons. The beam pipes and other parts of the machine may become activated during operations. This residual activity is a major source of exposure during maintenance.

State the meaning of the radiation unit rem.

Exposure is a quantity, originally defined to determine the output of x-ray machines, and the unit of measure is the Roentgen (R). The number of ions created when x-ray or gamma radiation passes through a specific volume of air defines the Roentgen.

Absorbed dose is the term used for quantifying all types of radiation, and relates the amount of energy deposited in any material by the radiation. The unit of measure for absorbed dose is the rad, which is equal to 100 ergs/gram deposited by any ionizing radiation in any type of material. The SI unit for absorbed dose is the gray (Gy), where 1 Gy = 100 rad.

When evaluating the risks associated with exposure to radiation in people, equal absorbed doses (rads) may not result in equal risks. This is partially due to the ability of some types of radiation to cause more biological damage, while depositing the same amount of energy. In other words, for equal absorbed doses of different types of radiation, the biological effects may be different. For the purposes of radiation protection and control, the unit rem is used when we are concerned about the biological damage or risk to people, rather than merely the absorbed dose.

The unit rem is used to relate the biological risk on a common scale for all kinds of ionizing radiation. The unit rem is the product of the absorbed dose in rads and a quality factor. The SI unit used to relate the biological risk on a common scale for all ionizing radiation is the Sievert (Sv), where 1 Sv = 100 rem. The quality factor is a multiplier used to account for the differences in the biological effectiveness of the different types of radiation.

Dose Equivalent (rem) = Absorbed Dose (rad) X Quality Factor

Dose Equivalent (Sv) = Absorbed Dose (Gy) X Quality Factor

Examples of quality factor for various radiations are:

Gamma and x-rays	1
Beta	1
Neutrons	2 - 10
Alpha	20

Neutrons have a range of Quality Factors to account for their ability to cause a varying amount of biological damage, depending on their energy. Low energy neutrons (less than .025 eV to 1.0 keV) have a Quality Factor of 2, while faster neutrons (100 keV to 1.0 Mev) have Quality Factors ranging from 7.5 to 10.

Dose and Dose Rate

The dose is a general term denoting the quantity of radiation or energy absorbed. In general, the term dose without any qualifiers refers to absorbed dose and is measured in rads. For the purposes of this course, dose refers to dose equivalent and is measured in rem, unless otherwise identified.

The dose rate is the rate at which the energy from radiation is absorbed. Because dose refers to the dose equivalent for this course, dose rate is generally measured in mrem/hour, unless otherwise identified.

When evaluating the risk of receiving radiation at a specific dose rate one must consider the duration of the exposure. The total dose can be determined by multiplying the existing dose rate (mrem/hr) by the duration of the exposure (hr).

TOTAL DOSE (mrem) = DOSE RATE (mrem/hr) X DURATION OF EXPOSURE (hr)

If an individual is planning to enter and area where the dose rate is 60 mrem/hr for a period of 30 minutes, that person's total dose could be calculated as follows:

TOTAL DOSE (mrem) = 60 mrem/hr X 0.5 hr.

TOTAL DOSE = 30 mrem

Differentiate between non-occupational and occupational radiation dose

Exposure to radiation is generally discussed in two broad categories, radiation doses to the general public (non-occupational) and radiation dose received while performing work at your place of employment (occupational).

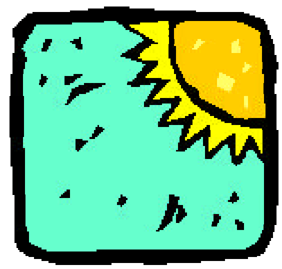
Sources of non-occupational radiation dose

Within the category of non-occupational radiation dose, sources of radiation can be further divided into natural background or man-made.

Man has been exposed to natural background sources of radiation throughout his history. The major natural background sources include:

Radon gas; comes from the radioactive decay of uranium which is naturally present in the soil. The radon gas can migrate through the soil and into the air. The decay products of radon attach to dust particles and may be inhaled. The decay products of radon will then deliver a dose to the tissue of the lungs. On Long Island, the dose from radon is much lower than the national average because there is very little uranium in the soil. The average annual effective dose equivalent from radon in the United States is **200 mrem**.

Cosmic radiation; which comes from outer space and our own sun. The earth's atmosphere and magnetic field affects the levels of cosmic radiation which reaches the surface, so your dose from cosmic radiation is determined by where you live. For example, the dose rate on Long Island (at sea level) is about 24 mrem/ year, while the dose rate in Denver, Colorado is 50 mrem/year. The average annual dose from cosmic radiation in the U.S. is **28 mrem**.



Terrestrial sources; exist because a number of materials have remained radioactive since the formation of the earth. These natural radioactive materials are found in the ground, rocks and building materials. Some of the contributors to terrestrial sources are the natural radioactive elements radium, uranium and thorium. In fact, there are some areas in Brazil where the natural background radiation levels reach 3,000 mrem/year. The average annual dose from terrestrial sources in the United States is **28 mrem**.

Internal source; our bodies contain various, naturally occurring radioactive elements, and potassium (^{40}K) is one of the major contributors to your internal dose. The average annual dose from internal sources in the United States is about **40 mrem**.

The major man-made sources that contribute to the radiation dose to the general public include:

Medical/dental sources; this includes diagnostic (such as chest or dental x-ray) and therapeutic uses of radiation (such as radiation therapy for tumors). Because medical and dental doses are so individualized, your dose may vary from a few millirem to several thousand mrem. The average dose from medical and dental sources in the United States is about **54 mrem/year**.

Consumer products; some consumer products contain small amounts of radioactive material. Examples include certain ceramic dishes (usually with an orange glaze), some luminous dial watches, and some smoke detectors. These consumer products account for a very minor contribution to the background dose. The average annual dose from consumer products in the United States is about **10 mrem**.

Other; this category includes radiation doses from fallout caused by bomb testing and accidents such as Chernobyl. The average annual dose from other sources in the United States is about **3 mrem**.

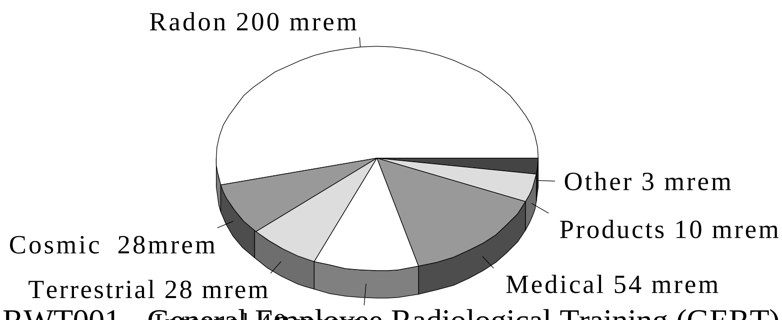
Sources of occupational radiation dose

The other broad category of radiation sources is occupational. Occupational dose is that which is received while working at your job. This includes any dose from previous employers, military or foreign business related travel. Occupational dose does not include doses received from background radiation, medical treatment or therapy.

Identify the average annual radiation dose from non-occupational sources

Overall, the average radiation dose to a member of the general population in the United States, from background and man-made sources is about **360 mrem/year**, or about 25,000 mrem over the average lifetime. On Long Island, this average dose is significantly lower because of the low levels of radon.

ANNUAL DOSE



Differentiate between acute and chronic effects

Acute Radiation Effects

Observable, short-term effects, often referred to as **acute effects**, are associated with large doses of radiation received in a relatively short period of time. Acute radiation effects typically will not occur at doses less than 10 rad. Below this level, the effect of radiation is too small to detect with today's medical technology. The first detectable effect is a minor change in the blood count. As the cumulative dose increases in magnitude, the effects become more observable. Examples of expected effects versus radiation dose include:

25 Rad	Onset of minor observable blood changes
100 Rad	May observe radiation sickness symptoms (nausea, diarrhea)
250 Rad	Possible hair loss
450 Rad	Established lethal dose LD50/30 (With no medical attention expected 50% mortality within 30 days)

Chronic Radiation Effects

In this course, a chronic dose is one received over a long period of time, usually repeatedly, in small increments. Examples of chronic doses include the dose received as a Radiological Worker at BNL (occupational dose) and the dose from background sources. Chronic doses may present an increased risk of a radiation induced cancer developing later in life ***There are no observable short term effects associated with a chronic radiation dose***. Within the allowed dose limits, this increased risk of a radiation induced cancer is considered small, especially when compared to risks people accept in their everyday lives.

Prediction of long term effects occurring are based on studies of people exposed to large doses, and include sample populations such as survivors of Hiroshima/Nagasaki, radium dial painters, radiotherapy patients, and uranium miners. The effects observed from these high doses are extrapolated to lower doses by assuming a direct, linear correlation. There has been some discussion about the appropriateness of these extrapolations from high dose to low dose, but scientific opinion generally concurs that these estimates are conservative.

State the potential effects associated with prenatal radiation dose

As with many other physical factors that are known to have an adverse effect on a developing embry or fetus, such as smoking, consuming alcohol, or caffeine, radiation exposure may pose harmful effects to the unborne child. The rapidly developing and immature cells of the developing embryo or fetus are more sensitive to damage, and the effects from exposure to radiation are no exception. The actual effects are a function of the time during gestation that the dose is received, and the amount of dose received. Studies have linked excessive radiation exposure to low birth weight, retarded growth and a potential increased risk of developing childhood cancer. Any harmful effect to the embryo or fetus (in utero) is called a teratogenic effect. The prediction of these effects occurring is based on studies from Hiroshima/ Nagasaki and pregnant women receiving radiotherapy. When compared to the normal risks associated with a pregnancy, risk of teratogenic effects from exposure to radiation up to the DOE limits (500 mrem/gestation period) is considered negligible. Current knowledge indicates that only when radiation doses exceed 15,000 mrem is there a significant increase in the risk.

Because the embryo/fetus is more susceptible to injury from radiation (compared to mature developed cells) DOE and BNL have a policy restricting the dose allowed to a declared pregnant Radiological Worker.

Identify the primary risk associated with occupational radiation dose

Based primarily on human studies, the National Academy of Sciences, National Council on Radiation Protection and Measurement, and the International Commission on Radiation Protection estimate the average risk (to an adult) of fatal cancer from radiation in his/her lifetime is **4 in 10,000 per rem**, using linear extrapolation.

To illustrate this, in a population of 10,000 people, current statistics indicate that approximately 3,000 will contract cancer in their lifetime. Of the 3,000 that develop cancer, approximately 2,000 will die from their cancer. If all 10,000 people were to receive 1,000 mrem (in addition to the radiation dose from natural background and man-made sources), an additional 4 deaths may occur due to radiation induced cancers. This increases the total fatality from approximately 2,000 to 2,004. This small effect cannot be "seen" in the normal variation of the death rates, and therefore must be calculated.

Another way of stating this is that a member of the general population in the United States has roughly a 20% chance of dying from cancer (natural cancer mortality rate). If this person were to receive an occupational dose of 1 rem (cumulative during his/her life), their risk of developing a fatal cancer would increase from 20 % to 20.04%.

Still, we assume that there is some probability for effects occurring even at very low doses. Simply stated, there is no threshold or starting point for an effect. This requires us to justify the need to receive these doses and ensure the benefit outweighs the risk. This "no threshold" concept is the basis for our ALARA (As Low As Reasonably Achievable) policy.

Compare occupational risk from radiation to health risks in industry and daily life.

The following tables may be used to gain perspective of the risk associated with exposure to radiation.

COMPARISON OF MORTALITY RATES

CAUSE	DEATHS/YR-MILLION PERSONS
Cardiovascular disease	4780
Cancer	1700
Motor accidents	220
Home accidents	150
Homicides	100
Fire	30
Drowning	30
Poisoning	13
Radiation effects (per rem)	9
Aircraft crashes	8
Electrocution	6
Lightning	1
Animal and insect bites	1

COMPARISON OF OCCUPATIONAL RISK

INDUSTRY	***AVE. EST OF DAYS LOST***
Mining and Quarrying	328
Construction	302
Agriculture	277
Radiation dose of 5 rem/year for 50 years	250
Transportation/Utilities	164
All industry	74
Government	55
Service	47
Manufacturing	43
Trade	30
Radiation accidents (deaths from exposure)	less than 1

COMPARISON OF DAILY LIFE RISK

ACTIVITY	***AVE. EST OF DAYS LOST***
Smoking	2,190
Overweight by 15%	730
Consuming alcohol (average US consumption rate)	365
Motor vehicle accident	207
Home accident	74
Drowning	24
Natural disaster	7
Radiation dose from medical applications	6
Receiving 100 mrem/year from age 18 to 65	5

As can be seen from these tables, the risk of death from radiation exposure is quite low compared to many other causes of death in our society.

Benefits of Radiation

Although the risks are low, some individuals are concerned about exposure to radiation, even at very low levels. These are personal value judgements that all individuals must make for themselves. Everyone should keep in mind that many uses of radiation are very important in health care or in other applications by society. The potential benefits of such use should be carefully weighed in consideration of the small risks produced by them. Some beneficial uses of radiation include:

1. Medical/Dental x-rays
2. Nuclear medicine scans (heart stress test, liver, bone, kidney, brain, etc.)
3. Cancer therapy
4. Biomedical research, such as DNA, cancer and immune system diseases
5. Airport security
6. Radiography for structural integrity
7. Food preservation

State the purpose and identify proper use of personal dosimetry

Whole Body Thermoluminescent Dosimeter Badge (TLD Badge)

In early 1996, Brookhaven National Laboratory replaced the film badge with the thermoluminescent dosimeter, called the TLD. The TLD performs the same function as the film badge, but is considered "State of the Art" in personnel dosimeter. This type of dosimeter is less sensitive to physical and environmental effects and unlike the film badge, can be reused after processing. As with the film badge, the TLD offers no protection from radiation, but monitors your exposure to beta, gamma and neutron radiation. TLDs are exchanged on a monthly basis and processed onsite. This processing usually takes a few weeks, unless there is a need for a quicker turn around in an individual case. There are many rules and requirements regarding the use of a TLD because the **TLD is the basis for the legal record of your occupational dose**.

These requirements include:

1. TLDs are worn when required by signs or postings, Radiological Work Permits, and when directed by Facility Support Representatives or Facility Support Technicians.

2. TLDs must be worn on the front of the torso, between the waist and the neck unless directed otherwise by the Facility Support Representative of the Facility Support Technician. The best location is the center of the chest with the label side of the badge facing away from the body.

3. When other type of dosimeters are required, they shall be worn adjacent to the TLD unless otherwise directed by a Facility Support Technician or Facility Support Representative.

4. The TLD should be placed on the designated badge board at the close of business. If the TLD is taken home by mistake, return it the next working day.

5. TLDs at BNL are usually exchanged the first week of each month.

    a. If you leave BNL (employment is terminated or your guest appointment has expired), turn your TLD in to the Facility Support Representative and cancel your TLD service.

    b. If you will not be here for the monthly exchange (e.g., business trip or vacation), leave your TLD on the badge board and it will be exchanged with the others.

    c. If you are wearing your TLD during the monthly exchange, see your Facility

Support Representative the next working day to exchange the badge.

d. Personnel that fail to return a TLD **may** be restricted from continued radiological work.

6. TLD issued at BNL should not be worn at another facility and dosimetry issued from another facility should not be worn at BNL. The concern is that your dose should be recorded only once for any time period monitored. If you have any questions or concerns, contact your Facility Support Representative.

7. Never wear another worker's TLD, nor should you allow another to wear your TLD. Because the TLD is issued to monitor an individual's monthly dose, either of these practices would invalidate the dose recorded on the TLD.

8. A red band on the front of the badge identifies visitor TLDs. Individuals wearing them require escort in radiologically controlled areas. If you encounter a visitor within a Controlled Area requiring dosimetry, who is not being escorted, immediately escort them out of the area requiring dosimetry. DO NOT PROVIDE ECORT FOR THEM UNLESS YOU ARE SPECIFICALLY ASSIGNED AS THEIR ESCORT.

   Persons successfully completing this training may be issued a TLD. Trained personnel receive a TLD with a blue or yellow band on the front of the badge. When TLDs are collected for monthly processing the used badge is exchanged with a new badge. To aid in determining whether all TLDs have been exchanged, the new TLD will have a different colored band. If you should notice that your TLD has a different colored band than most others, contact your Facility Support Representative and have your badge exchanged.

9. If you suspect the TLD has been misused or damaged in any way, (such as a trip through the laundry cycle or worn during a medical x-ray) you should notify your Facility Support Representative and a new TLD badge will be issued. **Wearers should never open or tamper with the TLD**.

10. Individuals working in areas controlled for radiological purposes should take specific actions if their TLD is lost, damaged, or contaminated. These actions include placing your work activities in a safe condition, immediately exiting the area and notifying your Facility Support Representative or Facilities Support Technician and your supervisor of the situation.

11. TLD results are your legal records of dose. Report any lost badge immediately, and if you find a TLD, turn it in to your Facility Support Representative. If you lose your badge or

fail to return it, an estimated dose is assigned to you based on your work activities and radiological conditions of your work sites. An investigation is required to determine your estimated dose which costs BNL time and money and is less accurate than reading the actual TLD.

Identify the annual radiation dose that a GERT qualified worker is expected not to exceed.

To minimize the potential risk of biological effects associated with radiation exposure, dose limits and administrative control levels (ACLs) have been established. The dose limits established by DOE for occupational workers are based on guidance from the National Council on Radiation Protection (NCRP), and the International Commission on Radiological Protection (ICRP). These DOE limits are also consistent with those of other agencies (such as the Nuclear Regulatory Commission) and other countries. The whole body dose limit for any radiological worker is 5,000 mrem in a year.

In order to assure that an individual's dose never approaches the dose limit and to ensure that management and the worker make conscious and informed decisions regarding allowing work to be performed. DOE, BNL and the Department have established ACLs that further restrict the worker exposure unless prior authorization is received to exceed these levels. The DOE annual ACL is 2,000 mrem and the BNL annual ACL is 1,250 mrem. In addition, each Department has its own level below the BNL level.

The information contained within this training course is commensurate to the radiological risks involved with the limited tasks that you are authorized to perform. You, as a GERT trained worker, may accessing only areas posted as Controlled Areas or Radioactive Material Areas within Controlled Areas and are allowed to handle only limited quantities of radioactive materials. For this reason, BNL has established radiation dose guidelines for GERT trained workers that are well below those authorized for personnel receiving the entire RadWorker 1 training.

Control of radiation dose

Individuals trained to the GERT level, who are not issued personal dosimetry are not expected to receive in excess of 100 mrem in a year. This is controlled utilizing radiological posting specifying the need for personal dosimetry. Any area exceeding 50 µrem/hr and with the potential of the occupational worker to receive in excess of 100 mrem in a year will be posted with personal dosimetry required for entry.

If a GERT trained person does not enter any area requiring personal dosimetry, that individual will likely spend the entire year (2000 hours) in areas with less than 50 μrem/hr or in areas where the annual dose will be less than 100 mrem.

$$\text{Thus } < 50\ \mu\text{rem/hr X 2000 hours} = < 100\ \text{mrem}$$

GERT trained individuals utilizing personal dosimetry may encounter radiation dose rates in excess of 50 μrem/hr. Because of this, there is a small potential for cumulative radiation doses to exceed 100 mrem in a year. Monthly TLD readings will be used to track the individual's cumulative dose to ensure his/her annual dose is maintained ALARA.

Prenatal Policy

Any women working in radiological areas, who becomes pregnant, has the option of voluntarily notifying her supervisor in writing that she is pregnant. Upon receipt of the written notification, she is classified as a "declared pregnant worker". Because of the woman's right to privacy, no action can be taken until the formal notification is received. The policy of BNL is to offer the declared pregnant work two work options. The first option is to identify a mutually agreeable assignment without loss of pay or promotional opportunity, such that further occupational radiation exposure is unlikely. This is frequently referred to as the “zero dose” option.

The second option, frequently referred to as the low-dose option, allows the declared pregnant worker to continue working in radiological areas with the DOE dose limit to the developing embryo or fetus of 500 mrem throughout the gestation period applied. For this class of declared pregnant worker, Brookhaven National Laboratory has established an administrative control level of 350 mrem throughout the gestation period to be received at a maximum rate of 40 millirem / month.

Whatever option the declared pregnant worker chooses, all benefits of her work, (pay, promotions, etc.) will not be affected. Furthermore, a declared pregnant work may revoke their declaration at any time during the pregnancy. At such time the normal radiation dose limits and ACLs apply. Finally, the declared pregnant worker must undeclare their pregnancy in writing in order to return to normal occupational worker status.

State the BNL management policy for the ALARA program.

Every person working at Brookhaven National Laboratory has a responsibility to themselves and their co-workers to work safely and maintain a safe working environment. Because there is a possibility, however small, of an effect occurring from any exposure to radiation, all doses are maintained As Low As Reasonably Achievable (ALARA).

Under the ALARA concept, DOE and BNL management policy includes:

1. Controlling radiation doses to workers and the public well below the regulatory limits.

2. Ensuring that no radiation exposure occurs without a corresponding benefit, and the benefit outweighs the risks associated with that dose.

3. Preventing unnecessary exposures to workers and the public.

4. Protecting the environment.

Individual Responsibilities

Individual responsibilities as GERT trained workers at BNL include:

1. Assuming the ***primary responsibility*** for maintaining your radiation dose ALARA, and below the dose limits and assigned administrative control levels.

2. Use time, distance, shielding to maintain your radiation doses low.

3. Maintain radiation interlock systems in a fully operational condition.

4. Read and comply with all radiation barriers, signs, labels and postings.

5. Do not climb over barrier fences, or defeat any radiological protection systems.

6. If you suspect that you are approaching or exceeding a dose limit or administrative control level, stop work, terminate your exposure to radiation, and report the situation to your supervisor and Facility Support Representative.

7. Comply with all regulations and orders establishing radiation dose limits and administrative control levels.

Apply the concepts of using Time, Distance and Shielding to reduce radiation dose.

Minimize Time of Exposure to Radiation

The main goal of the ALARA program is to reduce the radiation doses to a level that is **A**s **L**ow **A**s **R**easonably **A**chievable. Reducing the amount of time in a radiation area or field lowers the dose you receive. One of the keys in minimizing your time in a radiation area is to pre-plan the job or experiment. This may include:

1. Use of mock-ups to prove equipment or procedures, or to gain proficiency at the task to be done.

2. Taking the best route to the job site; the shortest route may not be the best - know where the higher and lower radiation level areas are.

3. Preparing the necessary tools and equipment prior to entering the area; verify any special calibration or tool preparation is done before entering the radiation area.

4. Never loitering in an area controlled for radiological purposes.

5. Working efficiently and quickly.

6. Eliminating rework by doing the job right the first time.

7. Performing preparatory work and parts assembly outside the area.

Increasing Distance from the Radiation Source

Use the protection offered by distance from the source of radiation when possible. For many sources, radiation levels decrease exponentially with increased distance. If the distance from the source is doubled, the radiation level decreases by a factor of 4. Some methods to increase the distance from the radiation source include:

1. During work delays, move to lower dose rate areas. Radiological surveys will have areas designated as Low Dose Rate Waiting Areas (LDRWA) clearly identified.

2. Using long handled tools, mechanical arms, and robotics to avoid higher dose rate areas.

3. Knowing the radiological conditions of the area you are entering. If possible, move the item being worked on away from the source of radiation, or move the source of radiation away from the work area.

4. Use of mirrors or closed circuit TV to monitor the job site.

Use Shielding to Lower the Dose Rate

Shielding reduces the amount of radiation dose to the worker.

1. Select the proper materials to shield a worker from the different types of radiation.

2. Take advantage of permanent shielding such as equipment or existing structures.

3. Position yourself so that shielding is between you and the source.

4. Wear safety glasses/goggles to protect the eyes from beta radiation, when applicable.

5. Install temporary shielding when required by procedure or the Radiological Work Permit (RWP). Temporary shielding is required to be marked or labeled with the statement: "Temporary Shielding - Do Not Remove Without Permission".

Interlocks and Shielding Design

In addition to individual workers using time, distance and shielding, Brookhaven National Laboratory embraces the ALARA concept with its design and use of engineering solutions such as shielding and interlock systems. Some of the basic interlock systems include:

1. Interlocks that prevent access.

2. Interlocks that turn off the source of radiation.

3. Interlocks that shield the source of radiation.

Because there are so many different interlock systems in use, specific operating instructions and concerns will be discussed when you receive facility specific training. In addition to the interlocks, alarms systems are also used to warn people of a hazardous condition or situation.

Identify the authorities granted to GERT trained individuals concerning access to radiological areas and control of radioactive materials

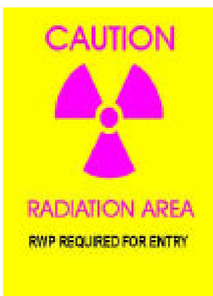
Postings are used to alert personnel of a potential or known radiological condition and to aid them in minimizing exposures and preventing the spread of contamination. Let's discuss the different areas on site and whether you will be permitted to enter that area with this training (GERT).

Controlled Area

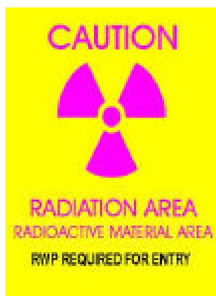
A Controlled Area is established to protect individuals from exposure to radiation and or radioactive materials. There are no significant radiation hazards in a Controlled Area. These areas are established surrounding other radiological areas that pose a risk and as such, require higher levels of control.

GERT training also allows you to handle low level, sealed radioactive sources. These are primarily small sources used for instrument response checks. You are ONLY allowed to access Radioactive Material Areas that are within Controlled Areas to obtain and store these radioactive sources. Be alert while working in Controlled Areas, read all radiological posting very carefully to ensure you do not enter other posted areas unless trained and authorized or accompanied by a trained escort.

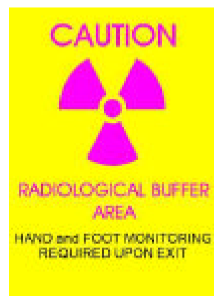
As a GERT trained person, YOU ARE NOT ALLOWED ACCESS to any other posted radiological area. Examples of other radiological posting include:



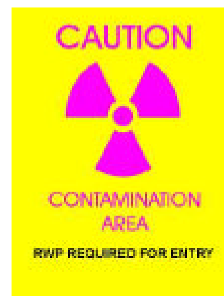
RADIATION AREA



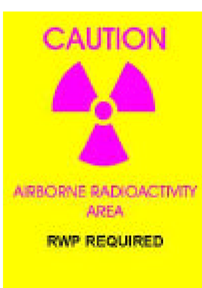
RADIOACTIVE MATERIAL AREA within a RADIATION AREA



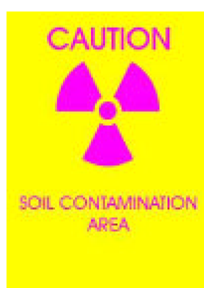
RADIOLOGICAL BUFFER AREA



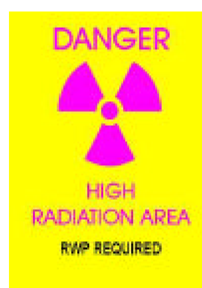
CONTAMINATION AREA



AIRBORNE RADIOACTIVITY AREA



SOIL CONTAMINATION AREA



HIGH RADIATION AREA

HIGH CONTAMINATION AREA

Identify the purpose and scope of the Price Anderson Amendment Act (PAAA) and 10CFR835 regarding matters involving radiological protection at BNL.

What is the Price-Anderson Amendment Act?

The Price-Anderson Amendment Act is a Congressional Act, designed **to protect the health and safety of workers and the general public**. The Act specifies that the Department of Energy (DOE) will insure its primary contractors (Brookhaven Science Associates) against liability arising from nuclear or radiological activities performed within the scope of the BSA contract.

DOE has put nuclear and radiological safety requirements into federal regulations. These regulations are contained within a document called the Code of Federal Regulations. (10 CFR 835).

The Code of Federal Regulations applies to three (3) categories:

- Quality Assurance applied to nuclear facilities and activities supporting nuclear facilities.
- Occupational Radiation Protection
- Procedural Rules and Enforcement Policies

To Whom Does This Apply?

PAAA applies to all DOE contractors such as Brookhaven Science Associates (BSA) as well as sub-contractors and suppliers to Brookhaven National Laboratory. This means that all employees, guests, contractors and outside suppliers are responsible to adhere to these regulations.
It is each and everyone's obligation and responsibility to identify, report and correct any known non-compliance issue. If these requirements are not met the primary contractor (BSA), sub-contractor, supplier and/or responsible individual may be liable to civil and/or criminal penalties and/or fines up to $110,000 / day.

What Must You Do If You Find A Requirement Has Not Been Met?

Upon discovering that a requirement has not been met it is your responsibility to report the deficiency to your immediate supervisor. It is very important not to overlook this requirement, ignorance is not an acceptable excuse.

If you knowingly allow a non-conforming activity to continue or during an investigation make fraudulent statements concerning the activity you may be held liable for willful negligence. Once reported, a preliminary investigation will take place to determine the applicability of the non-conforming activity. Results of the investigation will identify the root cause of the problem and comprehensive corrective actions to ensure the non-conforming activity does not recur.

What Can You Do To Ensure the Requirements are Met?

BNL management is responsible to provide each employee with adequate direction to ensure all work can be performed safely and within the regulatory requirements. Brookhaven National Laboratory utilizes an Integrated Safety Management (ISM) system to empower each and every person, at all levels, with the authority and responsibility to control and perform work safely.

BNL Senior Management

As the prime contractor, Brookhaven Science Associates (BSA) is responsible for the operation of Brookhaven National Laboratory under contract with the Department of Energy. As written, the contract is BSA's commitment to operate this facility in a safe and reliable manner, and for purposes of radiological protection, in compliance with all of the requirements specified within 10 CFR 835.

Radiological Control Manual

The BNL Radiological Control Manual specifies programmatic and implementation methods that BNL has adopted to satisfy 10CFR835 and the requirements of the contract. The requirements within the BNL Radiological Control Manual apply to all BNL activities that involve radiation or radioactivity that pose a potential hazard to workers, the public or the environment.

Radiological Control Division

Within the Environment, Safety, Health & Quality Directorate is the Radiological Control Division responsible for providing BNL Departments/Divisions with the necessary support and services to implementation the requirements of the BNL Radiological Control Manual. Your Facility Support Representative and Facility Support Technicians belong to the Radiological Control Division. These people are the experts assigned to your Division / Department that provide day to day radiological safety services such as:

1. Radiological safety reviews and job coverage for work and research projects.
2. Response to abnormal conditions and emergencies.
3. Radiological surveys
4. Job coverage for industrial hygiene and safety concerns

Employees, Guests and Sub-Contractors

As a GERT trained worker and a part of the BNL Team, it is each individual's responsibility to adhere to all BNL policies and procedures to ensure all work at the laboratory is performed safely and within the regulatory requirements.

Direction and guidance is provided to you in a variety of ways:

- Written Procedures

  When written procedures exist for your work, always follow the instructions. If you have questions, make sure they are answered BEFORE you start or continue with your job.

- Radiological Training

  Make sure you are aware of what training is necessary for your job and always ensure it is current BEFORE you start work. You can check your training status using the BNL Training and Qualification Web Page at:

  http://training.bnl.gov

- Radiation Work Permits

  As a GERT Worker, you would not normally encounter Radiation Work Permits (RWPs). However, under escort, you could have access to radiological areas which all require RWPs for access. Always obey all of the requirements contained within Radiation Work Permit (RWP). Read the permit carefully BEFORE you enter the area. If you have questions concerning the radiological conditions or protective measures, ASK questions. Don't assume anything without concurrence from a qualified Radiological Control Technician.

- Radiological Postings

  When working in or near radiological areas always READ and comply with area radiological signs and posting. In the event you find a radiological sign or posting misplaced or illegible, contact a Facility Support Technician for assistance. DO NOT alter or remove any radiological signs, postings or barricades.

Identify the purpose and scope of the BNL policy regarding your responsibility and authority for stopping non-compliant radiological work.

Stop Work for Radiological Activities

Radiological work is among the most important activities that we conduct at BNL. Management expectations for performing radiological work safely and fully compliant with regulations have been clearly stated by the Laboratory Director. The Director has empowered each and every individual who has received radiological safety training with the authority and responsibility to immediately stop non-compliant or unsafe radiological work. This policy is commonly known as the "Radiological Stop Work Policy".

Who Can Issue a Radiological Stop Work Order?

Any employee, guest, or visitor that has received formal training in the contents of the procedure through the successful completion of the GERT or RadWorker 1 training can issue a Radiological Stop Work Order.

If, while working a Radiological Stop Work Order is issued you MUST:

- Stop working on the affected activity as soon as safely possible.
- Place the workspace in safe condition.
- Report to your supervisor and explain why the Radiological Stop Work Order was issued at your job.
- Work is not to resume until safety reviews are performed and your department chairperson or equivalent line manager authorizes you to restart work.

It is essential that all BNL radiological control policies and procedures are respected. Our objective is to ensure excellence in radiological performance by utilizing the safety awareness and involvement of all personnel.

State the purpose of the BNL Radiological Awareness Report (RAR) Program.

Excellence in Radiological Controls is not merely having a good program, it also involves a continued desire to seek improvements throughout all levels of the program. To aid in continuing program improvement, Brookhaven National Laboratory has the Radiological Awareness Program commonly referred to as the RAR Program.

You, as a Radworker play a vital role in the success of this program. The RAR program is dependent on information gathered from radiological control practices in the field. It is the role of the Radworker to provide this information. This program is your avenue of communication between daily work activities and management concerning deficiencies in the administration of our Radiological Controls Program. In turn, with this information, management will be able to better identify program weaknesses and shortcomings, specify corrective actions and develop action plans for improvement.

If you have any questions regarding the RAR Program you may contact Bill Pemberton, RAR Coordinator at Ext: 4408